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Lead shot from hunting as a source of lead in human blood

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Birds hunted with lead shot and consumed are a source of lead in human blood

Abstract

This study investigates the relationship between the intake of birds hunted with lead shot and the lead concentration in human blood. Fifty adult men from Nuuk, Greenland took part in the study. From September 2003 to June 2004 they regularly gave blood samples and recorded how many birds they ate. We found a clear relationship between the number of bird meals and blood lead and also a clear seasonal variation. The concentration was highest in mid-winter when bird consumption is at its highest. Blood lead was low (15 μg/L, mean concentration) among the participants reporting not eating birds. Among those reporting to eat birds regularly, blood lead was significantly higher, up to 128 μg/L (mean concentration). Concentrations depended on the frequency of bird meals: the more the bird meals, the higher the resulting blood lead. This clear relationship points to lead shot as the dominating lead source to people in Greenland.

Keywords: Lead shot; Blood lead; Bird hunt; Bird meals; Human exposure

1. Introduction

The risk of health effects of lead traditionally is assessed by analyzing the concentration of lead in the blood. This concentration will reflect recent exposure, as the biological half-life for lead in blood is about 35 days (Gordon et al., 2002). Lead poisoning occurs at high lead concentrations in the blood. Gordon et al. (2002) describe symptoms like lethargy, anemia, headache and abdominal cramps at concentrations about 850 μg/L, but chronic effects have been seen at significantly lower blood concentrations, down to 100 μg/L and lower (ATSDR, 1999). These include effects on the hematological system, hypertension and renal function (ATSDR, 1999).

The most critical risk appears to be effects on the central nervous system of fetuses and children. Intelligence, reaction time, visual–motor integration, fine motor skills and attention in children were affected by blood lead concentrations between 50 and 100 μg/L, but also as low as 30 μg/L (Lanphear et al., 2000; Canfield et al., 2003; Chiodo et al., 2004). U.S. Centers for Disease Control (USCDC, 1991) has defined 100 μg/L as a level of medical concern, but mentions that there may not be a "safe" lower limit.

For centuries, humans have been exposed to man-made sources of lead in the environment, among these, mining and refining of lead, tubes and house hold articles, batteries, gasoline, paint and ammunition. Today several of these sources, for example, leaded gasoline, are not important because their use has been regulated. As a result human lead exposure has decreased. For example, during the past two decades, the proportion of US children who have blood lead concentrations of 100 μg/L or higher declined by over 80% after the elimination of leaded gasoline, lead solder from canned foods and leaded paint used in housing and other consumer products (Lanphear et al., 2003). However, certain socio-economic groups still have a disproportionate number of people with elevated tissue-lead levels, such as minority groups in North America (Pirkle et al., 1998) and substance hunting groups in Canada (Tsuji et al., 2001).

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In Greenland the sources mentioned have also been important. In the late 1970s, the blood lead levels in Greenland were as high as in large West European cities (Hansen, 1981; Hansen et al., 1983). Also in Greenland blood lead levels are declining, but were at the most recent study generally higher than in other Arctic regions and Scandinavia (AMAP, 2003; Bjerregaard and Hansen, 2000). Bjerregaard et al. (2004) consider it most likely that a phasing out of leaded gasoline in the late 1990s causes this decline and that this was a significant source earlier, both from combustion and from handling of gasoline.

Another important lead source to humans in Greenland has been and still is the use of lead shot in bird-hunting. In a study conducted in 1993–1994, Bjerregaard et al. (2004) found a positive correlation between the number of bird meals and the lead concentration in blood from 228 randomly selected Greenlanders. In this study there was no correlation between blood lead and other local diet items (fish, seal or whale) or imported food. This is in accordance with the finding that the lead concentration in local Greenland diet is very low (Dietz et al., 1996). Consequently human lead intake from the local diet is very low, estimated to be 15 μg per person per week (Johansen et al., 2000), while the intake of lead from birds hunted with lead shot is high. Johansen et al. (2004) estimated an average lead intake of 146 μg from one meal of thick-billed murre (*Uria lomvia*) and of 1220 μg from one meal of common eider (*Somateria mollissima*). This was even after having removed whole shot pellets and visible fractions of these from the bird meat before analyzing it. Based on these studies, Johansen et al. (2004) conclude that birds hunted with lead shot probably is the most important lead source to humans in Greenland. Studies in other Arctic regions (Canada and Russia) indicate that this is also the case here (Hanning et al., 2003; Odland et al., 1999b; Scheuhammer et al., 1998; Tsuji and Nieboer, 1997). In Canada analyses of teeth have been used to assess chronic lead exposure. Tsuji et al. (2001, 2003) saw elevated lead in deciduous teeth from remote communities in northern Ontario and associated this to lead intake from game hunted with lead shot.

In Greenland birds are primarily eaten seasonally. Therefore, the relationship between the average consumption of seabirds and the blood lead levels measured at one point in time in an earlier study (Bjerregaard et al., 2004) may not be a true description of the relationship. This was the background for initiating this study. Here bird consumers were followed before, during, and after the bird-hunting season in order to establish the association between consumption of birds and blood lead concentrations as well as peak concentrations. A seasonal variation of blood lead levels related to a hunting season is indicated in a study of Northern Quebec First Nation Cree inhabitants. Their blood lead levels increased during the two months following the goose hunt, when compared to initial levels (Kosatsky, 1998).

2. Materials and methods

The Primary Health Care Center in Nuuk selected 50 men to take part in the study together with KNAPK (The Fishermen and Hunters Association). The mean age of the participants was 55, varying from 35 to 78. All were ethnic Greenlanders and in good health status. Some were hunters supplying the local market with birds hunted near Nuuk. The criterion was to include persons who would eat many birds and persons who would eat few. The plan of the study was to follow the individual person's blood lead in the months before, during and after the bird-hunting season, which is mainly from November to April, by taking blood samples in September, November, January, March and May.

Ethical approval was obtained from the Commission for Scientific Research in Greenland. Informed consent was obtained verbally and in writing.

Each participant was handed a dietary questionnaire developed specifically for this study because there are no standardized questionnaires on traditional Greenlandic diet available. The questionnaire was of the food frequency type and included a list of the following diet items: murre, eider, kittiwake, ptarmigan, "other bird species", musk ox, caribou, hare, fish, seal, whale and "Danish food". The participant was asked to report daily which of these were parts of the diet from September 2003 through May 2004.

At the Primary Health Care Center in Nuuk, blood samples were taken by venous puncture in fossa cubitti in polyethylene test tubes with EDTA as an anticoagulant (terumo venoject) and frozen at −78 °C. They were transported frozen to the National Environmental Research Institute in Roskilde, where they were kept at −20 °C until analyzed for lead.

All samples were analyzed by Inductively Coupled Plasma-Mass Spectrometry, ICP-MS, Agilent 7500 ce. The lead isotopes 206, 207 and 208 were used to quantify the results against commercial standard solutions. About half of the samples were also analyzed by means of atomic absorption spectrometry, AAS, Perkin Elmer graphite furnace model Aanalyst 800 (Asmund and Cleemann, 2000). Good agreement was obtained between the two methods, but with a tendency of lower concentrations (mean 8.4%) for the ICP-MS compared to the AAS method (correlation coefficient 0.96). All samples were supplemented by blanks and one or two certified reference materials for every 13 samples. The certified materials were Tort-2, Dorm-2 and Dolt-3 from the National Research Council of Canada. The detection limit, defined as 3 times the standard deviation for blanks, of the AAS method was calculated to be 5 μg/L, and that of the ICP-MS method to 9 μg/L. Results for both the AAS and the ICP-MS methods were used in the data analysis.

Prior to the statistical analyses, concentrations were logarithmic (base e) transformed to reduce skewness and better fit parametric requirements. In most cases the log-transformed concentrations did not differ significantly (Shapiro–Wilk test, $p > 0.05$) from normality. Data analyses included linear regression to assess the relationship between the mean number of bird meals and the mean blood lead concentration. The parametric Pearson correlation analysis was used to evaluate the relationship between bird intake and the resulting lead blood concentration. One-way analysis of variance followed by Tukey's Studentized Rank test was used to test differences in blood lead between different groups of exposure, defined from the mean number of bird meals per month of the group. Finally, a moving average smoother using a fixed window of 30% of the largest independent variable range was applied to graphically describe blood lead concentrations before, during and after the bird-hunting season.

3. Results

Only about half of the participants made daily recordings of their diet. The diet composition per month therefore in several cases was reconstructed by interviewing people when sampling their blood. After this we critically evaluated all dietary questionnaires and computed the frequency of the different diet items. As the objective of this study was to correlate blood lead with bird intake, we have only included diet data, which we consider to describe the monthly intake of birds. This means that some monthly diet data were excluded from the data analysis, including all data from three participants.

3.1. Diet composition

Birds were recorded to be part of the diet of 1300 meals from 1 October 2003 to 31 May 2004. These were composed of 61% murres and 29% eiders. Other bird species thus constitute an insignificant part and they have been left out from the data analysis. It is notable that murres are mainly eaten from November to March while eiders are part of the diet later in the season (mainly January to June) as illustrated in Fig. 1.

3.2. Human lead exposure and blood lead levels

We have evaluated the relationship between the participant's bird intake and their blood lead concentration in different ways.

Firstly, we have made a regression analysis of the mean number of bird meals per month and the participant's mean blood lead concentration (logarithmic transformed) over the whole study period (Table 1). There is in all cases a positive relationship between these two variables, and only in the case of murre the relationship was not significant at the 5% level.

Secondly we have made an analysis where we have correlated the blood lead concentration with "recent exposure" from murre and eider meals. We used this procedure to simulate that the blood lead concentration of a person at a given point of time is expected to reflect this person's lead intake before the blood sample is taken. If the blood sample was taken between the 1st and the 20th in a month, we have defined "recent exposure" as the number of bird meals in the preceding month. If the blood sample was taken after the 20th in a month "recent exposure" is the number of bird meals in the same month.

In an earlier study we found significantly higher lead concentrations in eiders than in murre, in average a factor of 8.31 (Johansen et al., 2004). This means that the lead exposure depends on the species eaten. To take this into account when

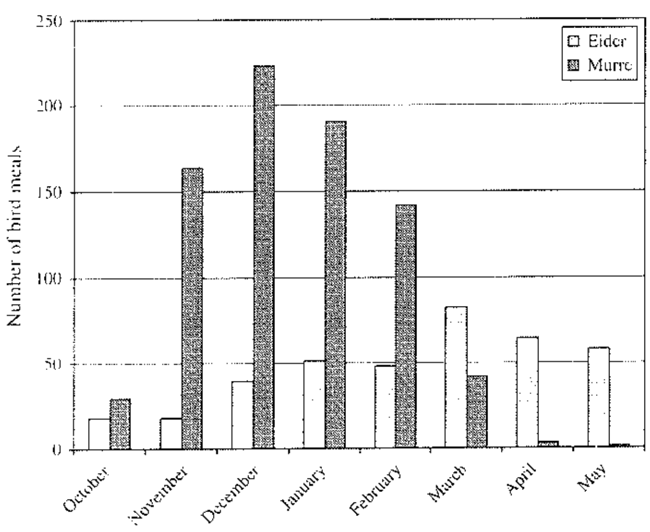

Fig. 1. Number of meals of murre and eider per month.

Table 1
Regression analysis of the mean blood lead concentration on the mean number of bird meals per month

	Mean no. of bird meals (min–max)	Slope of regression line	R^2	Sign. level
Murre + eider	0–9	0.098	0.14	0.011
Eider	0–4	0.208	0.15	0.007
Murre	0–7.5	0.101	0.07	0.075

evaluating blood results, we have made a calculation of the lead exposure from what we call "a bird equivalent", which we define as the sum of murre meals per month and eider meals per month multiplied by 8.31.

Pearson's correlation analyses showed that in all cases there is a significant positive correlation between most recent bird meals and the resulting blood lead level, lowest for murre and highest for the calculated "bird equivalent" (Table 2). Table 2 (like Table 1) shows that eider meals are more important than murre meals as a lead source in the blood.

In the third analysis we have divided the participants into five so-called exposure groups from their average number of meals per month of murre and eider, computed as "bird equivalents" as defined above. The exposure groups were defined from the data. We selected a group eating no birds as one and a group eating many (>30 birds) as another. The three groups in-between we defined with increasing number of bird meals in each group (0.1–5, 5.1–15, 15.1–30) in order to obtain similar number of observations in each group. The five groups and their computed mean blood lead concentrations are shown in Table 3. It is seen that the mean blood lead concentration increases from group A (0 bird equivalents per month) to group E (>30 bird equivalents per month). An analysis of variance of log-transformed blood lead concentrations shows that there is a very significant difference between the exposure groups ($F = 6.79$, $p < 0.0001$). Tukey's test revealed that group A is significantly lower than all other groups, while group B does not differ from group C and groups C, D and E do not differ significantly (Table 3). To illustrate the seasonal variation we have computed the blood lead concentration of the five exposure groups in the study period. The result is shown in Fig. 2. Over season the pattern is the same with group A as the lowest increasing through groups B, C and D towards the highest concentrations in group E. The unexposed group (A) shows no clear seasonal pattern, while blood lead in the most exposed group (group E) continues to increase throughout the study period. This fits with the observation that eiders gives the highest exposure and at the same time mainly are eaten late in the bird-hunting season.

Table 2
Correlation between bird intake and the resulting blood lead concentration

	Pearson corr. coefficient	Sign. level
Murre	0.19	0.004
Murre + eider	0.30	<0.001
Eider	0.29	<0.001
Bird equivalent	0.32	<0.001

3 1 Diet composition

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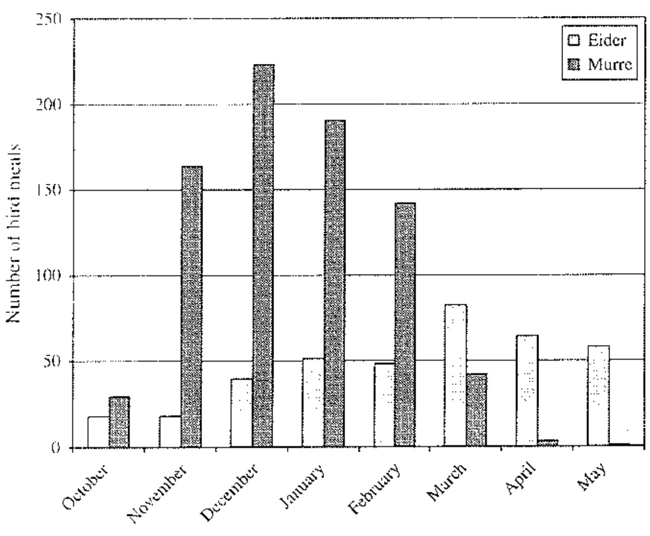

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Table 3
Exposure groups and their blood lead concentrations (μg/L)

	Bird equivalents per month	N	Mean conc	St.dev	Min	Max
Group A	0	4	15	7	7	2
Group B^{a}	0 1–5	73	62	48	25	211
Group $C^{a,b}$	5 1–15	31	74	47	12	221
Group D^{b}	15 1–30	42	82	45	20	190
Group E^{b}	>30	5	128	36	87	154

Groups with same superscript letter did not differ significantly (Tukey's test)

In the three medium exposed groups (B C and D) the tendency is an increase of the blood lead concentration from September to March followed by a decrease until June

4. Discussion and conclusions

There is a clear relationship between the number of bird meals and the blood lead concentration of the participants in this study which also shows that eiders are more important as a lead source than murres These findings support our conclusion from an earlier study of lead in murre and eider meat indicating that lead shot used to kill these birds are an important lead source to people in Greenland (Johansen et al 2004) This was also indicated in a study in Greenland conducted in 1993–1994 (Bjerregaard et al 2004)

4.1 Concentration levels

The blood lead concentration is low (mean 15 μg/L) in the group of participants reporting not to eat birds This is comparable to the level (median 12 μg/L) found in young mothers from Northern Norway and among the lowest reported levels in adult populations (Odland et al 1999a) and lower than in a study of Danes in the late 1990s (mean 35 μg/L, Nielsen et al 1998) In contrast the blood lead concentration in bird eaters from Greenland are significantly higher (mean 62–128 μg/L, see Table 3) This clear difference points to lead shot as the dominating lead source to people in Greenland

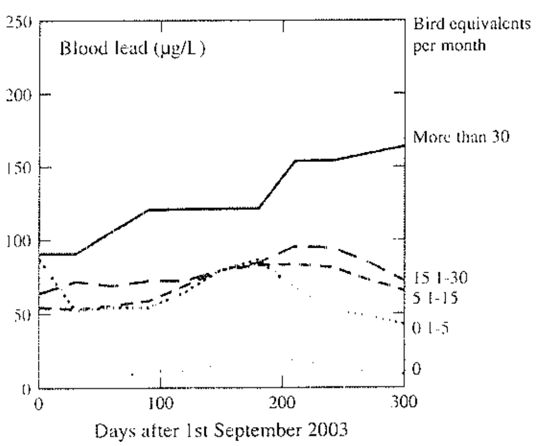

Fig 2 Blood lead concentration (μg/L) depicted against date of blood sampling expressed as the number of days after 1 September 2003 for each exposure group as defined in Table 3 Lines represent mean smoothing functions as described in Section 2

There is, however, individual deviations from the general pattern found in this study Some of the participants have relatively high blood lead concentrations in spite of reporting low bird intake This indicates that one or more other lead sources affect them. One possibility is that they carry lead shot in the intestine. A way to test this would be to X-ray their abdomen, however, this is not done for that purpose on the hospitals Another way could be to study the isotopic composition of the blood lead

Other studies have shown that lead shot in the intestine leach lead to the blood and it has been claimed that this may cause lead poisoning (Madsen et al, 1988; Hillman, 1967) This is also mentioned in a case from Greenland, where the blood lead concentration decreased and the symptoms of lead poisoning disappeared in a patient, when his appendix with six lead shot pellets was removed (Johansen and Nygård, 1987) In Greenland it has not been systematically studied to what extent people carry lead shot in their intestine In a study of a Canadian group of First Nation's people where traditional diet including hunted game is significant, Tsuji and Nieboer (1997) found that 15% carried lead shot in the intestine

This phenomenon may also explain that the exposed groups in Greenland already have a relatively high blood lead concentration before the start of the bird-hunting season (see Fig 1) Another possibility is that they have eaten kittiwake This species is mainly hunted (killed with lead shot) in August and September. It was also recorded as a diet item in this study and may thus have been a source before the start of the main bird-hunting season

Another explanation that some of the people reporting eating few birds have relatively high blood lead levels could be that the specific birds these people did consume were highly contaminated with lead The variation of lead concentration in the birds is very large (Scheuhammer et al, 1998; Tsuji et al, 1999; Johansen et al, 2004) The amount of lead pellets or fragments embedded in the tissue is likely to be related to the experience of the hunter For example, experienced hunters can shoot down birds in the head and not destroy the body with lead pellets People consuming birds hunted that way would have a low lead exposure In our data there are indications that this could be the case, as some people have relatively low blood lead levels in spite of reporting eating many birds

4.2 Health effects

The highest single measured blood lead concentration in this study was 221 μg/L This is 3–4 times lower than the level that could be expected to cause lead poisoning, but effects on the hematological system, hypertension and renal function is a possibility among the participants with the highest blood lead concentrations

However, the most critical risk of lead in humans appears to be effects on the central nervous system of fetuses and children Blood lead concentrations between 50 and 100 μg/L but also as low as 30 μg/L may have an impact (Lanphear et al , 2000; Canfield et al 2003; Chiodo et al , 2004) This is also potentially a risk in Greenland, as fetuses will be exposed to elevated blood lead concentrations when the mother consumes birds hunted with lead shot In an earlier study of mothers and their newborns, the mean blood lead concentrations of different mother groups varied from 24 to 50 μg/L, with single values varying from 9 to 180 μg/L (Deutch, 2003) This study also showed that the fetus has almost the same blood lead concentration as the mother It thus seems likely that blood lead levels found in Greenland might affect development of the central nervous system in fetuses among the mothers most exposed to lead

It is also likely that there is a risk to children as some of these will consume birds hunted with lead shot as part of their meals However there are no blood lead data from Greenland children, so possible health effects cannot be assessed Therefore a study on blood lead of children should be initiated

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